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AGRICULTURAL MEMORANDUM 558

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Harvest Moisture Content of Barley Grain

This memorandum gives a relatively simple method for calculating grain moisture content from weather data after the grain has stopped growing. Details of the derivation are given as an appendix.

N.B. Grain moisture content is expressed on the wet basis throughout.

A). Drying of Standing Grain.

During dry weather the grain moisture content (M%) is related to potential transpiration (E mm.) by,

$$M = 46.8\ E^{-0.354}$$

(for E greater than 3 mm)...(1)

For E less than 3 mm. use linear interpolation between M = 40% and M = M(2).

B.) Wetting by Rain

Let t (in hours) be the duration of moisture uptake due to free surface water on the ears. Normally t is taken to be the duration of rainfall. Then for t greater than 2 hours,

$$M = 40 - (40 - Mi)e^{-0.145.\ t\ + 0.132}\ ...(2)$$

Mi is the moisture content at the start of rain.

M is the grain moisture content after time t hours.

When t is less than 2 hours it is necessary to linearly interpolate between Mi and M(2).

C.) The Method Applied to Spring Barley.

1). July 20th is chosen as the date when grain dry matter increase has stopped, and the grain moisture content is 40%.

2). Obtain daily values of potential transpiration from July 20th to the harvest date.

3). Obtain the duration of each period of rainfall.

4). Use equations (1) and (2) for each dry and wet period to obtain values of grain moisture content at different times including the harvest date.

Tests of the Method.

The European Brewery Convention trial data for Sparsholt (Hampshire) were used to obtain the grain moisture content figures at harvest. These figures give the average moisture content for between 4 and 12 barley varieties, depending on the complexity of the trial.

Daily rainfall amounts were available for Sparsholt, while sunshine and the sequence of daily weather observations, was obtained from Boscombe Down. This DWR station is situated about 17 miles to the north west of the trial site.

Daily values of potential transpiration P mm., were obtained using

$$P = 1.5 + 0.25 X \quad ....(3).$$

X is the daily sunshine value.

For values of X less than 0.5 hr. the relative humidity from the 12.00 and 18.00 hrs. readings at Boscombe Down was used to adjust the value obtained from eq.(3). For example, if X = 0 and the Boscombe Down humidity and weather sequence indicated 100% relative humidity all day, then P = 0.

The duration of rainfall was estimated from the amount of rain at Sparsholt and the reported pattern of rainfall intensity at Boscombe Down. These estimates could be in error by 10-15%, or more in showery situations.

Results.

Year	Observed harvest moisture content (% wet base)	Calculated moisture content (%)
1954	17.9	18.0
1955	11.3	12.3
1956	20.8	19.0, 20.2
1960	15.9	15.4
1966	13.8	13.5
1967	13.2	15.3
1968	15.3	16.0
1969	12.2	14.1

In 1956 a shower occurred during the harvest day and the two numbers are the maximum and minimum for that day.

The "calculated moisture content" column is the figure for the end of the harvest day and should therefore be the minimum moisture content to be expected. There is some tendency to overestimate the moisture content at harvest, particularly in dry years (1955, 1967, 1969), but refinements to equations (1) and (2) are probably worthless

in view of the unrepresentativeness in the basic weather data.

Practical Considerations.

It became clear during the moisture content calculations that the harvest moisture content was more dependent upon the weather a few days before harvest than the weather 15 days or more before harvest. Rain early on in the drying period does not seriously affect the time taken to reach a moisture content suitable for harvest. However, if the grain has dried to say, 15% M.C. by 10th August, then rainfall after this can increase considerably the moisture content, and nullify the previous drying. A period of 10 to 12 hours rain can raise the moisture content from 15 to 30 or 35% (wet base) and a week of dry weather with average sunshine is required to bring the moisture content back to 15%. Similarly a period of 3 hours wetting with the moisture content initially at 15% would require 3 or 4 good drying days to achieve 15% again.

Showers do less to increase the moisture content than prolonged rain even though the rainfall amounts may be considerable. A sharp shower lasting 15 min. which gives 2 mm. might increase the grain moisture content from 15 to 15.5% (according to calculation), whereas the same rainfall amount spread over 2 hours could increase the moisture content to 18.5 or 19%. In the shower situation a good afternoon's drying is sufficient to remove the effects of the shower, but for the other case 2 or 3 good drying days are necessary.

Appendix : Derivation of Equations (1) and (2).

1). Wetting by Rain - Equation (2).

The upper limit of grain moisture content for barley and wheat grains after prolonged soaking is taken to be 40% (wet basis). This agrees approximately with data from malting results and is the figure chosen by Brück and Van Elderen (1969). These authors also present a graph of an experiment on Spring wheat which shows grain moisture content measured 12 times per day during August 1967, together with a graph of precipitation. During that time 10 periods of rain occurred whose associated wetting durations varied from 2 to $7\frac{1}{2}$ hours. For each wetting period it was assumed that the moisture content had an exponential response starting from the initial moisture content Mi, with 40% as the upper limit for infinite wetting duration, i.e.

$$M = 40 - (40 - Mi)e^{-kt}$$

M is the grain moisture content after t hours wetting, Mi is the initial grain moisture content and k is a constant. In order to find k, $\ln[(40-Mi)/(40-M)]$ was plotted against t for each spell of rain. The correlation was +0.73 with k = 0.145, but the intercept was considerably different from zero (-0.132). The final equation is therefore,

$$M = 40 - (40 - Mi)e^{-0.145\,t + 0.132} \quad \ldots\ldots(2).$$

Equation (2) does not fit the variation of M with t for small values of t, since the right hand side reduces to Mi for t approximately equal to 3/4 hour. This can be overcome by restricting eq. (2) to values of t greater than 2 hours and by assuming a linear variation of M with t between Mi and M(2).

Dew is not considered as wetting the grain. This is wrong, but some allowance for dew has probably been made in determining equation (1) - the drying curve.

2). The Drying Curve - Equation (2).

The drying curve for grain given by Crampin and Dalton (1971) in terms of equilibrium moisture content gave higher harvest moisture contents than those actually observed. There were some limitations of the basic data however. Relative humidity was available at Boscombe Down 4 times per day so that the estimation of the duration of specific values of humidity is uncertain. The 'day' value of relative humidity (mean of 12.00 and 18.00 hrs. readings) was assumed to apply for 14 hours, while the 'night' value (mean of 00.01 and 06.00 hrs. readings) applied for 10 hrs. Differences in these details cannot affect the final result, since the equilibrium moisture content was higher than the observed grain moisture content values on the harvest day.

Brück and Van Elderen (1969) have published a moisture content - time curve for grains initially soaked in water and then placed in a current of warm dry air. It is assumed that the shape of this drying curve is the same for grain in the field. This amounts to the assumption that the resistance of the grain to moisture loss is the major factor which determines water transport, and that this resistance is the same in wind tunnels or in the field. It is necessary to replace their time scale by a potential transpiration scale. Initially some European Brewery Convention barley trials with rainless (or nearly so) ripening periods were used. Only 2 trials satisfied this condition (Spain and Portugal, 1965) and for these potential transpiration was estimated for the drying period and related to the observed moisture content at harvest.

This drying curve was then used to predict harvest moisture contents at Sparsholt in 1954 and 1955. The calculated moisture contents were considerably higher than the observed values, and the potential transpiration scale was adjusted to fit the data in 1954 and 1955. This required a transpiration scale approximately twice as compressed as the scale derived from the Iberian data. It is doubtful that this could be due to errors in estimating transpiration, but may be caused by a faulty grain moisture measurement caused by dew first thing in the morning. The final form of the curve is equation (1) which gives an approximate fit to the data.

Drying Curve : actual moisture contents and figures derived from equation (1).

Moisture content % wet base

Emm	0	3	5	7	10	15	20	25	30	40	60
Data	40	32.2	28.0	24.8	21.6	18.5	16.1	14.6	13.7	12.7	11.0
Fitted Curve (Eq. 1).	40	31.7	26.5	23.5	20.7	17.9	16.2	15.0	14.0	12.7	11.0

Wetting curves : calculated moisture content after t hours wetting and for different initial moisture contents (Mi).

t hrs. / Mi % wet base	½	1	2	3	4	5	7	10	15
30	30.4	30.7	31.5	32.6	33.6	34.5	35.9	37.3	38.7
25	25.6	26.1	27.2	28.9	30.4	31.7	33.8	36.0	38.1
20	20.7	21.5	22.9	25.2	27.2	28.9	31.7	34.6	37.4
17	17.8	18.7	20.4	23.0	25.3	27.3	30.5	33.8	37.0
15	15.9	16.9	18.7	21.5	24.0	26.2	29.7	33.3	36.8
14	15.0	15.9	17.8	20.8	23.4	25.6	29.2	33.0	36.6
13	14.0	15.0	16.9	20.1	22.8	25.1	28.8	32.8	36.5
12	13.0	14.0	16.1	19.3	22.1	24.5	28.4	32.5	36.4

References

Brück, I.G.M., Van Elderen, E. 1969. J. Agric. Engng. Res. 14(2) 105-116.

Crampin, D.J., Dalton, G.E. 1971 J. Agric. Engng. Res. 16(1) 88-91.

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